



FIG. 2

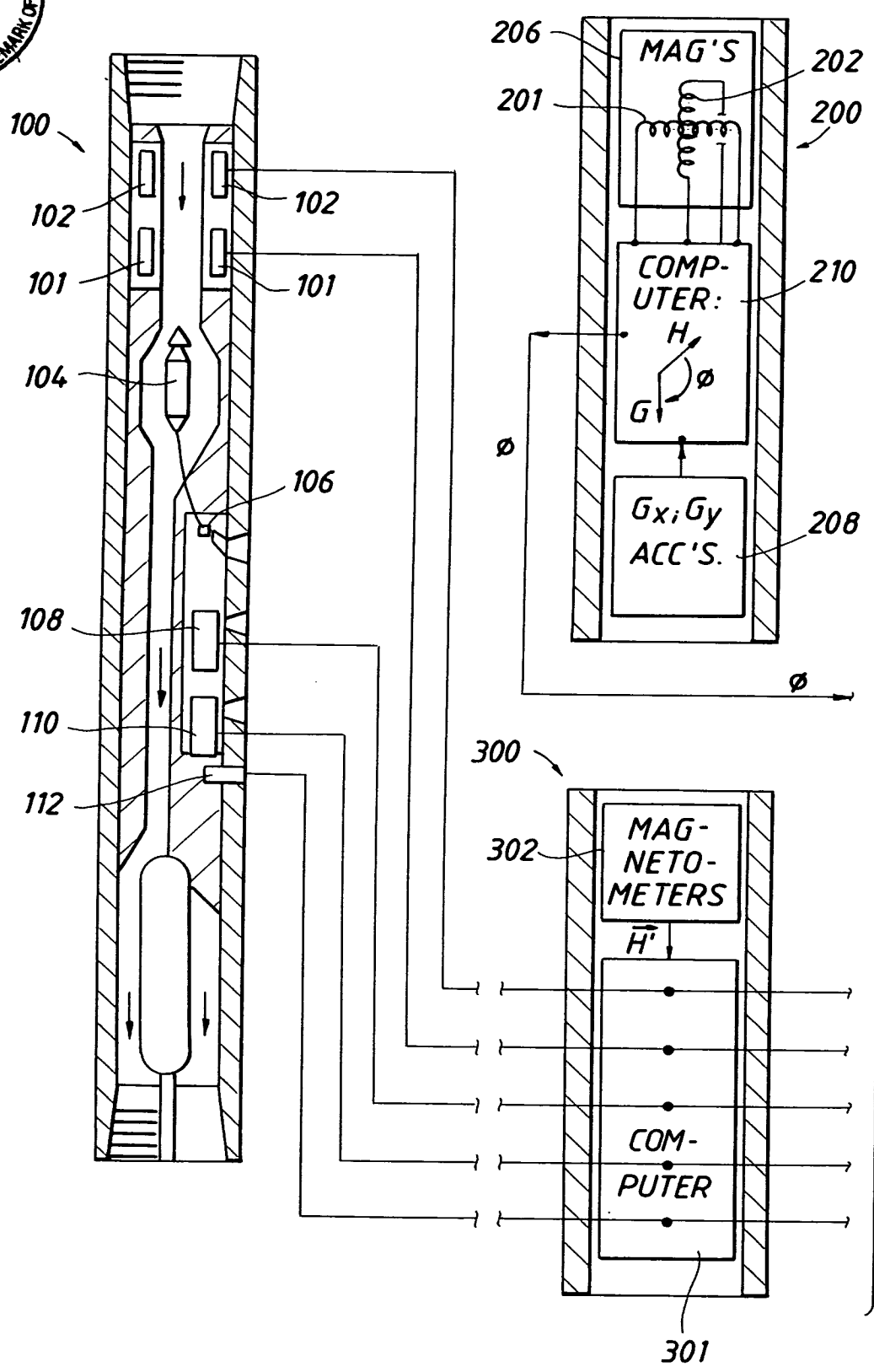


FIG. 3A

FROM FIG. 3A

$\frac{\phi}{H'}$

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FROM FIG. 2

DOWNHOLE COMPUTER

QUADRANT/SENSOR  
 POSITION DETERMINATION

310

DATA ACQUISITION PROGRAM

- FAR NEUTRON COUNT RATE
- NEAR NEUTRON COUNT RATE
- SHORT SPACED GAMMA RAY COUNT RATE
- LONG SPACED GAMMA RAY COUNT RATE
- STANDOFF

315

FIG. 3B

PROGRAMS

320

BULK DENSITY PER ENTIRE BORE-HOLE AND QUADRANT

301

326

ROT DENSITY PER ENTIRE BORE-HOLE AND QUADRANT

330

AVG PEF PER ENTIRE BOREHOLE AND QUADRANT

335

ROT PEF PER ENTIRE BOREHOLE AND QUADRANT

340

NEUTRON POROSITY PER ENTIRE BOREHOLE AND QUADRANT

345

ROT NEUTRON POROSITY PER ENTIRE BOREHOLE AND QUADRANT

350

ULTRASONIC STANDOFF (CALIPER) PER QUADRANT

FIG. 4A

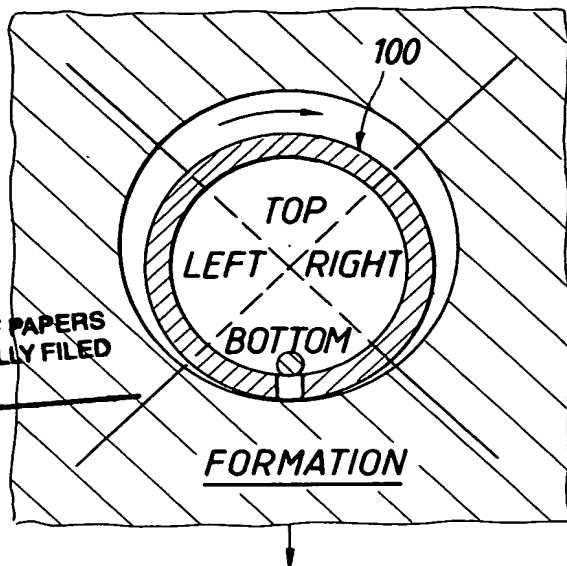


FIG. 4B

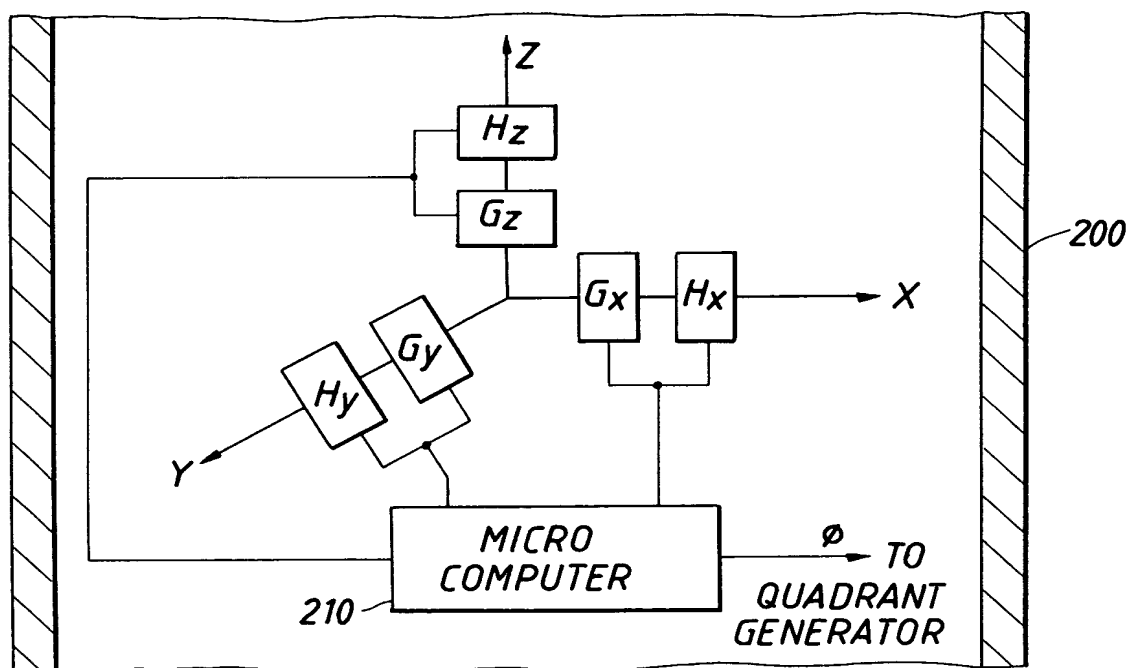
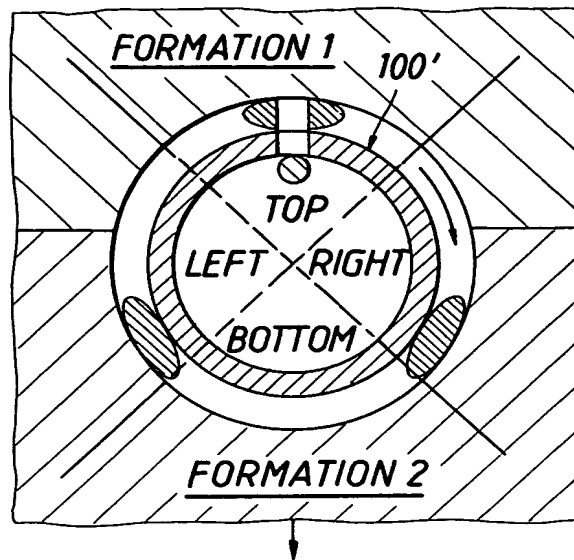


FIG. 5A

FIG. 5B

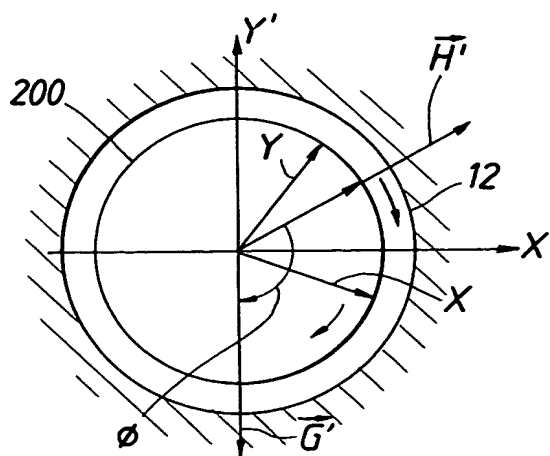
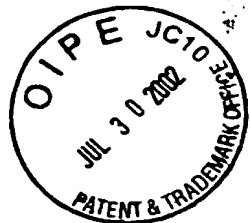
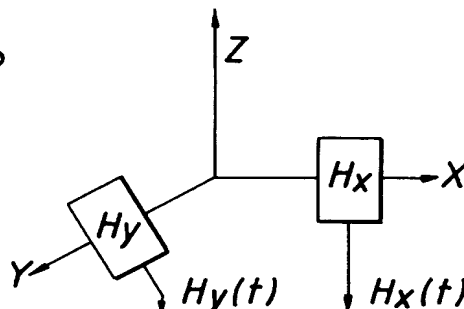


FIG. 6A



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MAGNETOMETER  
SECTION



QUADRANT/SENSOR POSITION DETERMINATION  
COMPUTER PROGRAM

DETERMINE DOWN DIRECTION

- DETERMINE  $\vec{H}'(t)$  VECTOR FROM  $H_x(t)$ ,  $H_y(t)$ ,  $\Delta\theta(t)$

- DETERMINE DOWN DIRECTION ANGLE

$$\theta = \cos^{-1} \frac{H_x(t)}{(H_x^2 + H_y^2)^{1/2}}$$

$\phi$  →  $\Delta\vec{H}(t) = \theta(t)$  AS MEASURED FROM TOOL X-AXIS  
 $\Delta\vec{D}(t) = \theta(t) - \phi$  AS MEASURED FROM TOOL X-AXIS

- DETERMINE BOTTOM QUADRANT

$$Q_{BOT}(t) = \Delta\vec{D}(t) - 45^\circ \text{ TO } \Delta\vec{D}(t) + 45^\circ$$

$$Q_{LEFT}(t) = \Delta\vec{D}(t) + 45^\circ \text{ TO } \Delta\vec{D}(t) + 135^\circ$$

$$Q_{TOP}(t) = \Delta\vec{D}(t) + 135^\circ \text{ TO } \Delta\vec{D}(t) + 225^\circ$$

$$Q_{RIGHT}(t) = \Delta\vec{D}(t) + 225^\circ \text{ TO } \Delta\vec{D}(t) - 45^\circ$$

- DETERMINE QUADRANT OF SENSOR

$\Delta\vec{S}(t)$  IS MEASURED FROM X-AXIS AND  $\vec{H}'(t)$  VECTOR

$\Delta\vec{S}$  IS  $\propto$  DEGREES FROM X-AXIS

$\Delta\vec{H}(t)$  IS  $\theta(t)$  DEGREES FROM X-AXIS

$\Delta\vec{S}(t) = \alpha$  AS MEASURED FROM X-AXIS IS

IN  $Q_{BOT}$  WHEN  $\Delta\vec{S}(t) = \alpha$  IS BETWEEN  $\theta(t) - \phi - 45^\circ$  AND  $\theta(t) - \phi + 45^\circ$ , ETC.

FIG. 6B

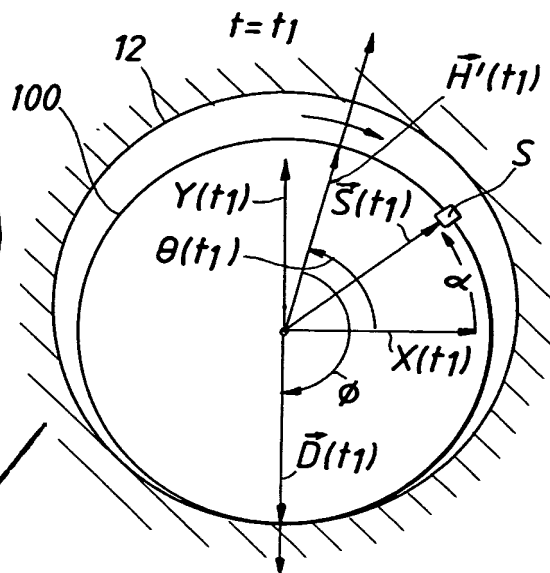
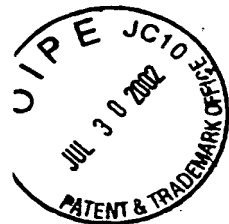
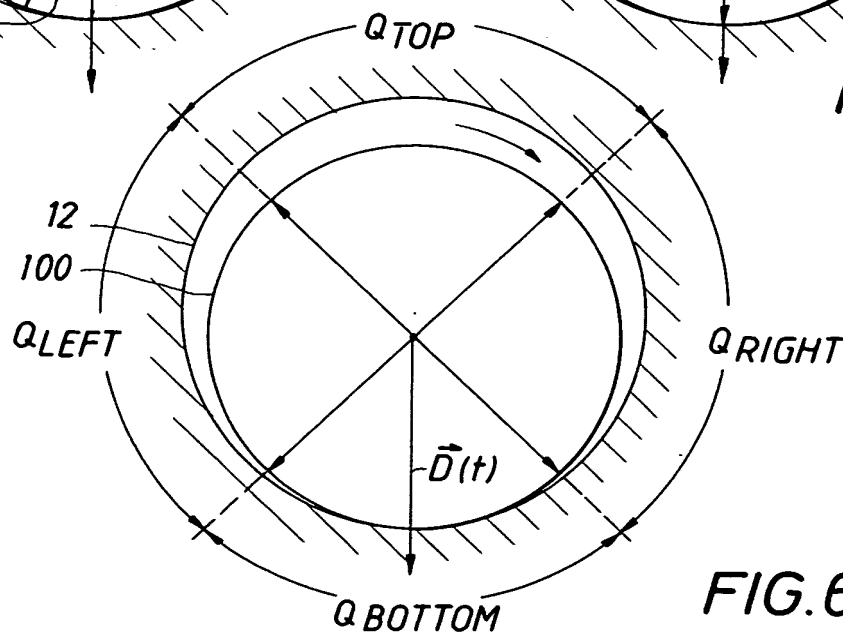
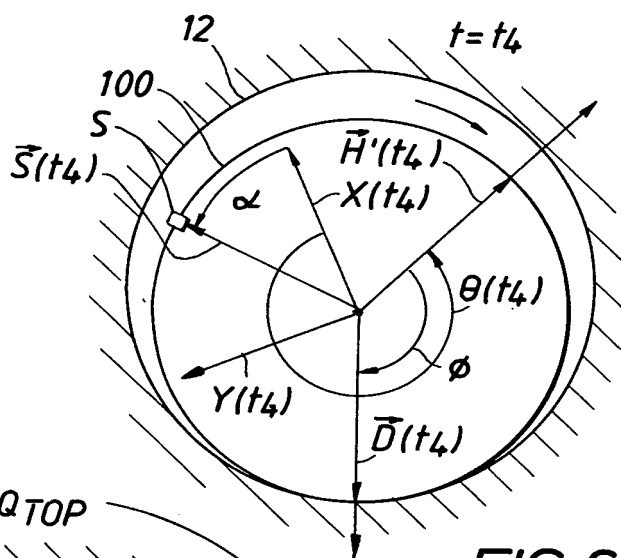
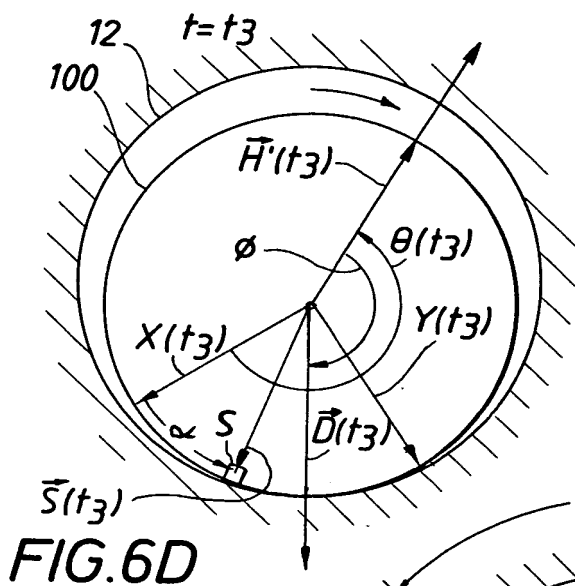
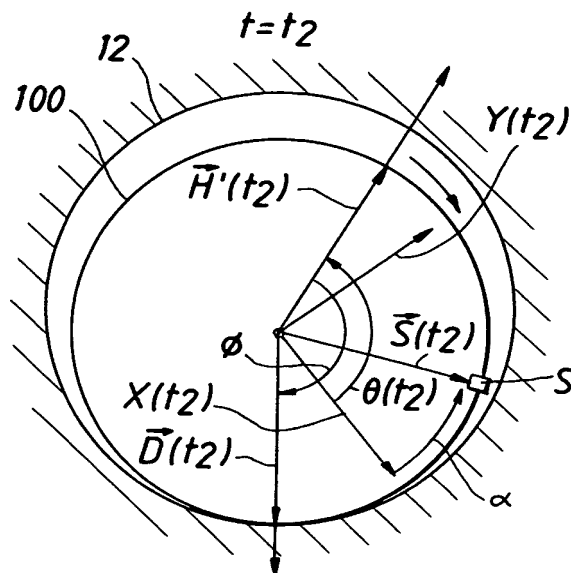
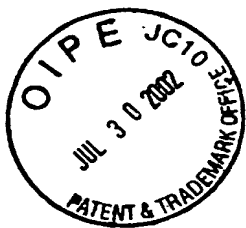


FIG. 6C



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FIG. 7A

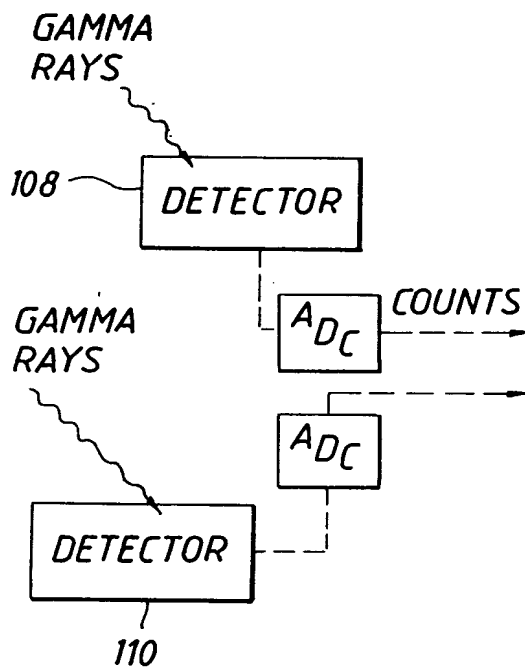


FIG. 7B

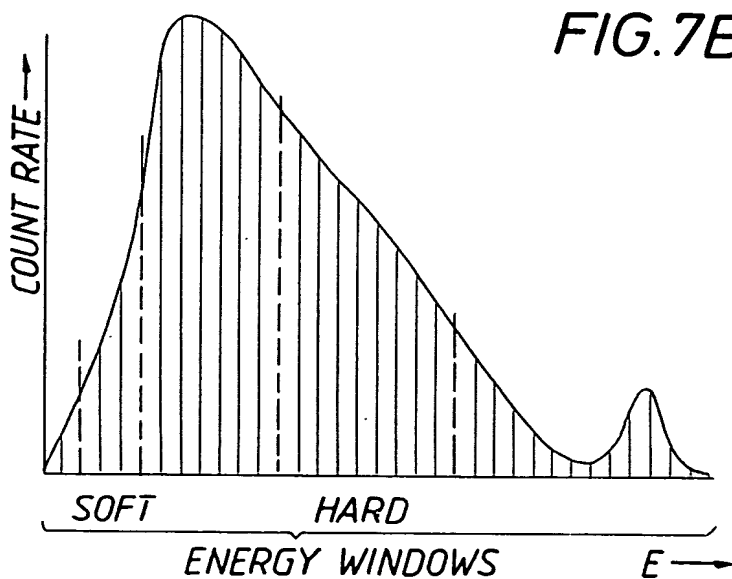
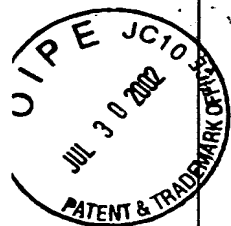


FIG. 8

315



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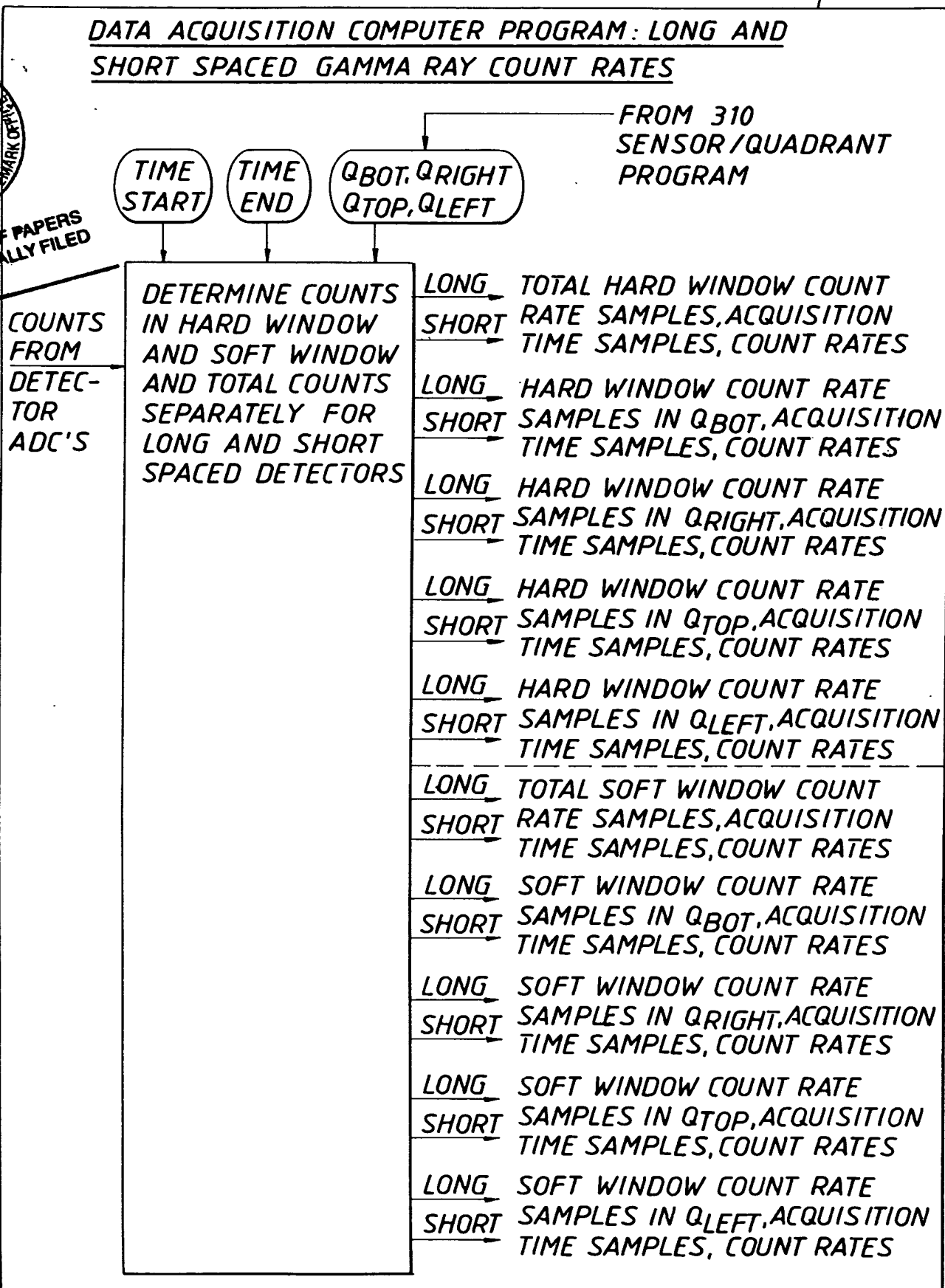
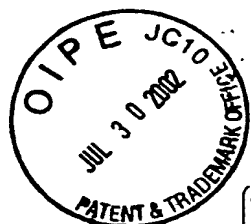




FIG. 9

320



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FROM FIG. 8

COMPUTER PROGRAM FOR BULK DENSITY OUTPUTS

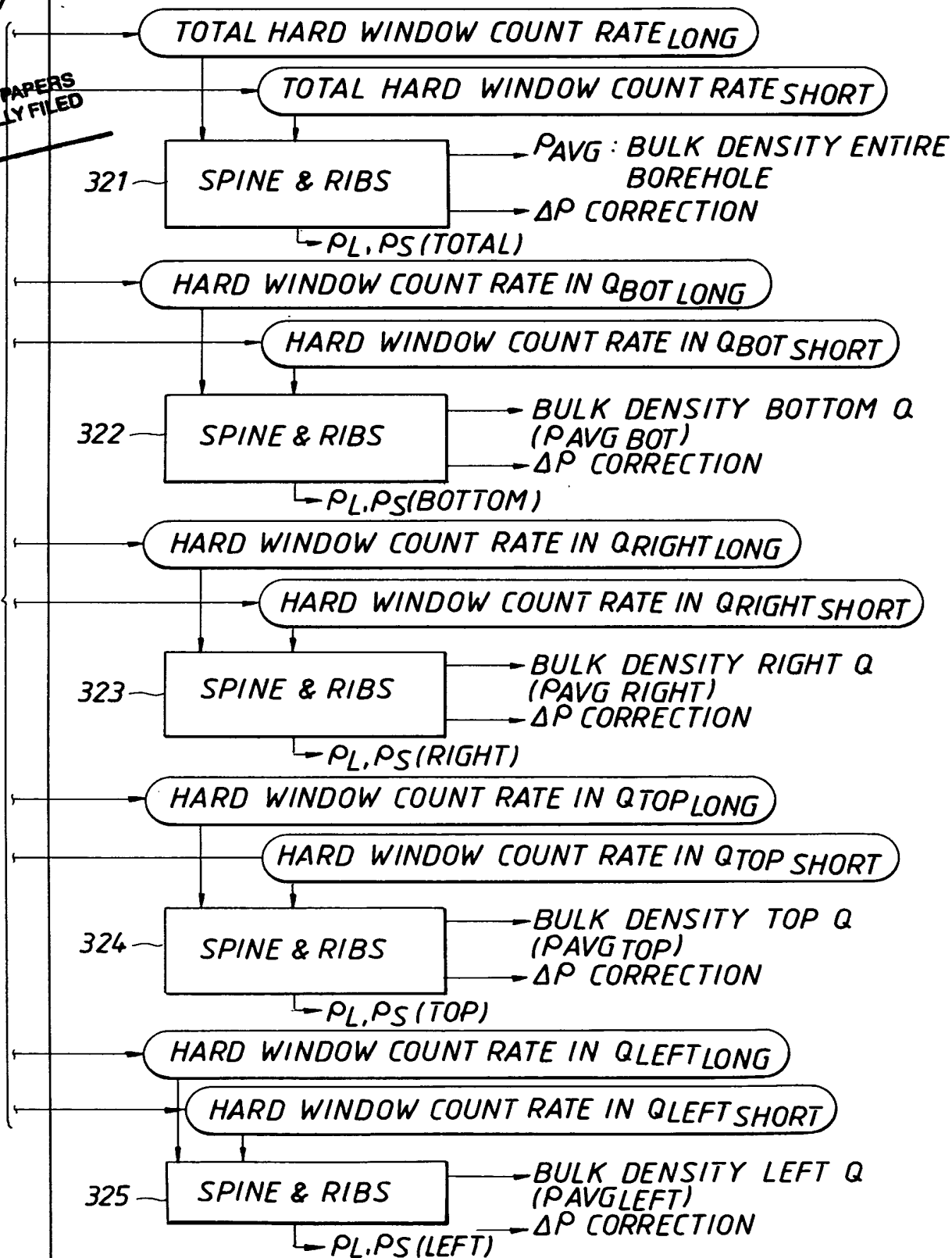
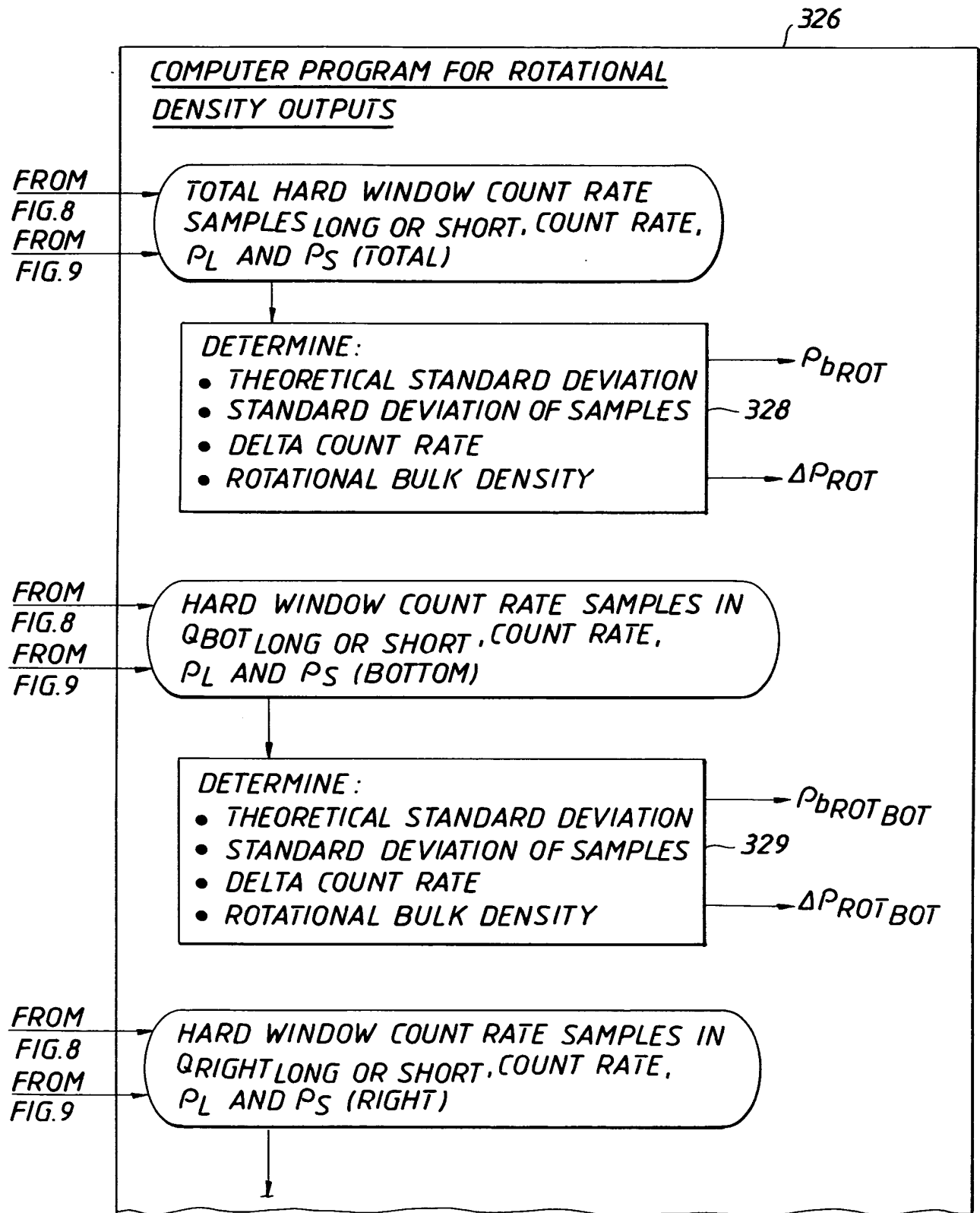
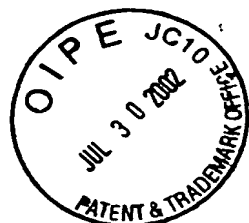


FIG. 10A-1



TO FIG. 10A-2

FIG.10A-2



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FROM FIG. 10A-1

FROM  
FIG. 8  
FROM  
FIG. 9

DETERMINE:

- THEORETICAL STANDARD DEVIATION
- STANDARD DEVIATION OF SAMPLES
- DELTA COUNT RATE
- ROTATIONAL BULK DENSITY

$P_{bROTRIGHT}$   
330  
 $\Delta P_{ROTRIGHT}$

HARD WINDOW COUNT RATE SAMPLES IN  
 $Q_{TOPLONG}$  OR SHORT, COUNT RATE,  
 $P_L$  AND  $P_S$  (TOP)

DETERMINE:

- THEORETICAL STANDARD DEVIATION
- STANDARD DEVIATION OF SAMPLES
- DELTA COUNT RATE
- ROTATIONAL BULK DENSITY

$P_{bROTTOP}$   
331  
 $\Delta P_{ROTTOP}$

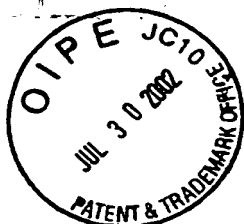
FROM  
FIG. 8  
FROM  
FIG. 9

HARD WINDOW COUNT RATE SAMPLES IN  
 $Q_{LEFTLONG}$  OR SHORT, COUNT RATE,  
 $P_L$  AND  $P_S$  (LEFT)

DETERMINE:

- THEORETICAL STANDARD DEVIATION
- STANDARD DEVIATION OF SAMPLES
- DELTA COUNT RATE
- ROTATIONAL BULK DENSITY

$P_{bROTLEFT}$   
332  
 $\Delta P_{ROTLEFT}$



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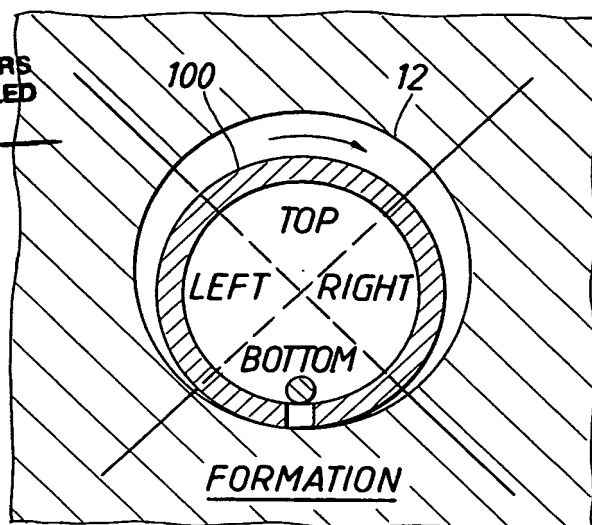


FIG. 10B

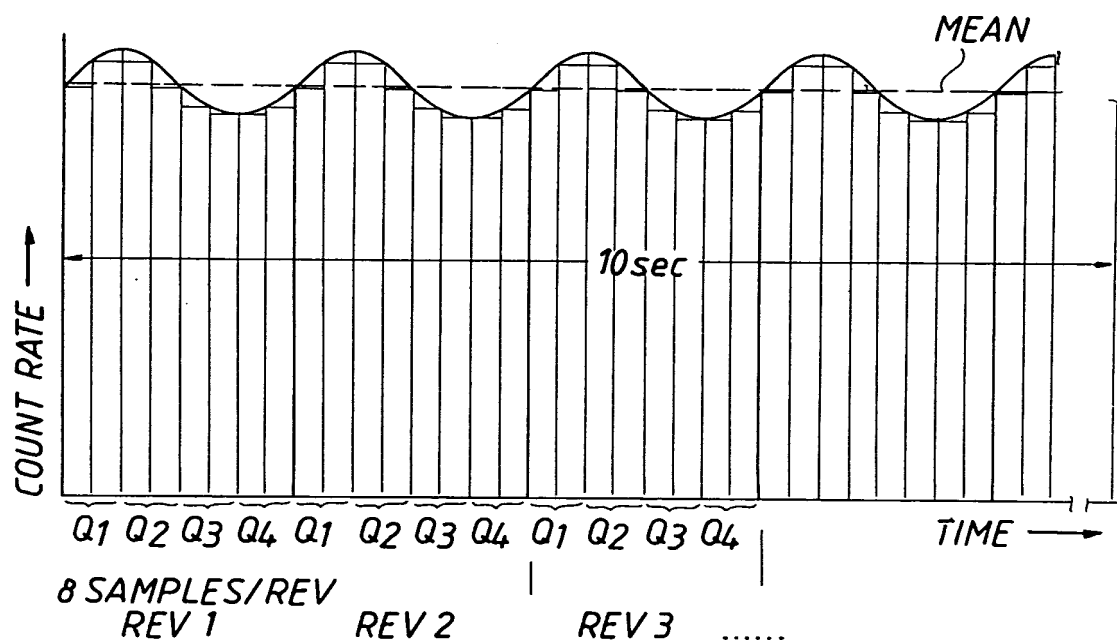
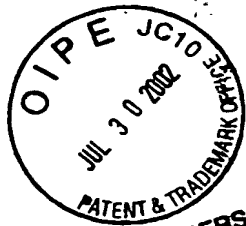
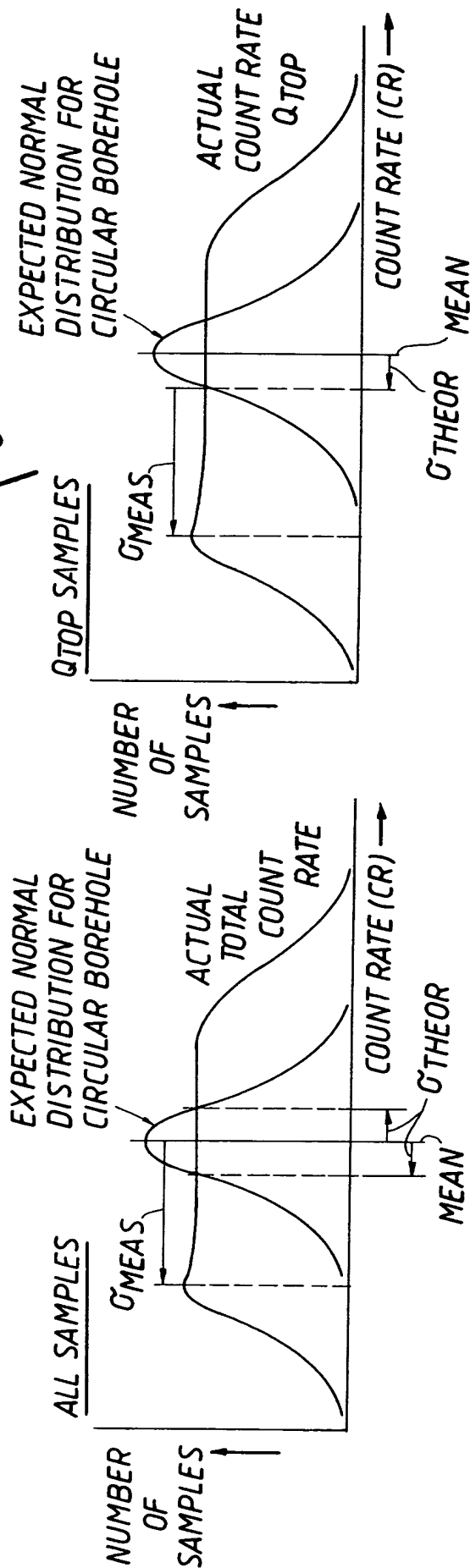


FIG. 10C



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$$\Delta CR = A \sqrt{G^2_{MEAS} - G^2_{THEOR}}$$

$$\Delta P_{ROT} = (ds) \left[ \ln \left( \frac{CR + \Delta CR}{CR - \Delta CR} \right) \right]$$

$$P_{bROT} = DPL * EPS + F \Delta P_{ROT}$$

$$PL = \text{LONG SPACING DENSITY}$$

$$PS = \text{SHORT SPACING DENSITY}$$

FIG. 10D-1

$$\Delta CR_{TOP} = A \sqrt{G^2_{MEAS_{TOP}} - G^2_{THEOR_{TOP}}}$$

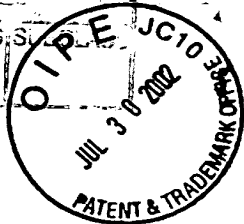
$$\Delta P_{ROT_{TOP}} = (ds) \left[ \ln \left( \frac{CR_{TOP} + \Delta CR_{TOP}}{CR_{TOP} - \Delta CR_{TOP}} \right) \right]$$

$$P_{bROT_{TOP}} = DPL_{TOP} * EP_{STOP} + F \Delta P_{ROT_{TOP}}$$

$$PL_{TOP} = \text{LONG SPACING DENSITY}_{TOP}$$

$$PS_{TOP} = \text{SHORT SPACING DENSITY}_{TOP}$$

FIG. 10D-2



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FIG. 11A

330

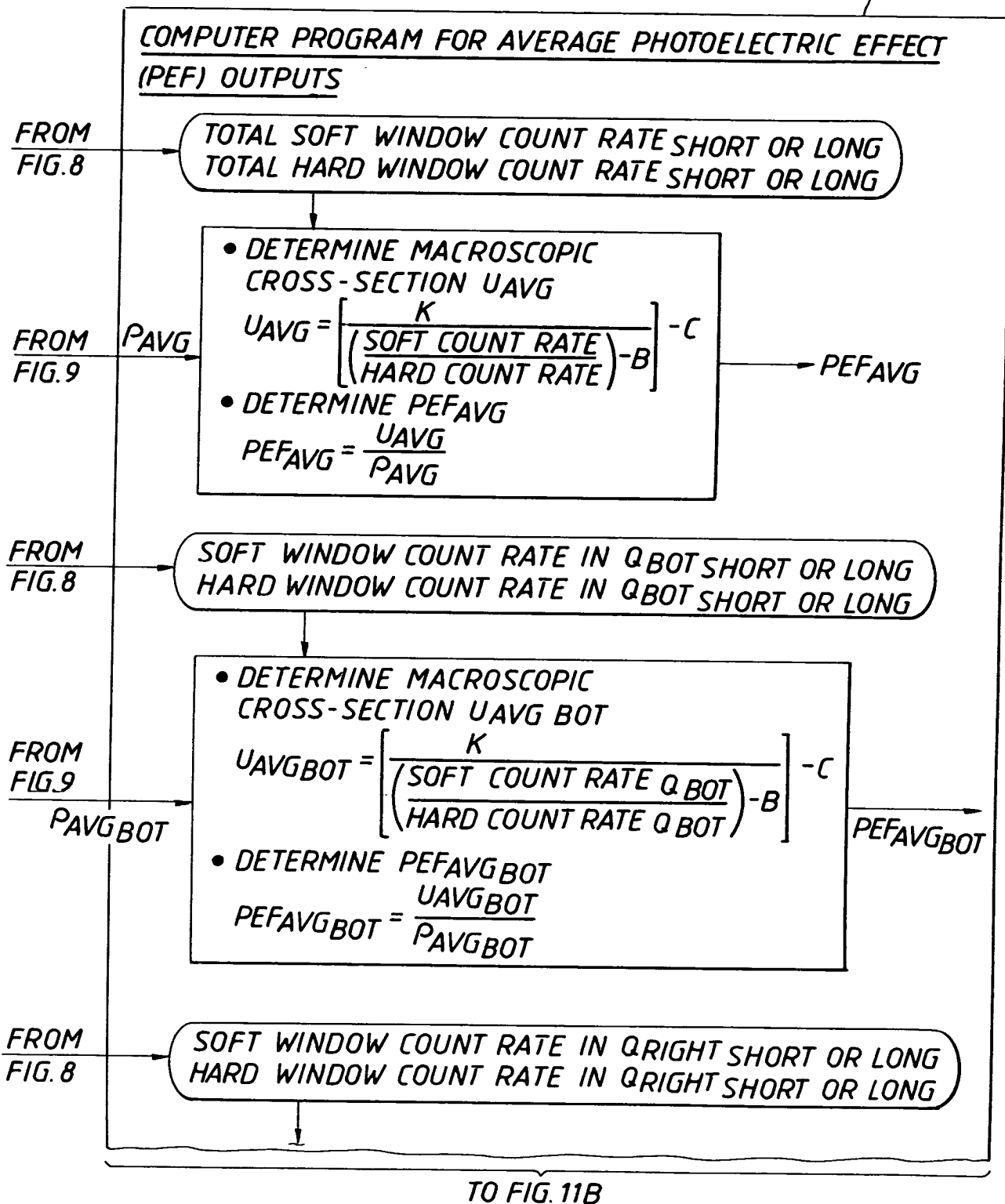


FIG. 11B

FROM FIG. 11A

FROM  
FIG. 9  
PAVG<sub>RIGHT</sub>

- DETERMINE MACROSCOPIC CROSS-SECTION UAV<sub>RIGHT</sub>

$$UAV_{RIGHT} = \left[ \frac{K}{\left( \frac{\text{SOFT COUNT RATE } Q_{RIGHT}}{\text{HARD COUNT RATE } Q_{RIGHT}} \right)^{-B}} \right]^{-C}$$

- DETERMINE PEFAV<sub>RIGHT</sub>

$$PEFAV_{RIGHT} = \frac{UAV_{RIGHT}}{PAVG_{RIGHT}}$$

PEFAV<sub>RIGHT</sub>

FROM  
FIG. 8

SOFT WINDOW COUNT RATE IN Q<sub>TOP</sub> SHORT OR LONG  
HARD WINDOW COUNT RATE IN Q<sub>TOP</sub> SHORT OR LONG

- DETERMINE MACROSCOPIC CROSS-SECTION UAV<sub>TOP</sub>

$$UAV_{TOP} = \left[ \frac{K}{\left( \frac{\text{SOFT COUNT RATE } Q_{TOP}}{\text{HARD COUNT RATE } Q_{TOP}} \right)^{-B}} \right]^{-C}$$

- DETERMINE PEFAV<sub>TOP</sub>

$$PEFAV_{TOP} = \frac{UAV_{TOP}}{PAVG_{TOP}}$$

PEFAV<sub>TOP</sub>

FROM  
FIG. 8

SOFT WINDOW COUNT RATE IN Q<sub>LEFT</sub> SHORT OR LONG  
HARD WINDOW COUNT RATE IN Q<sub>LEFT</sub> SHORT OR LONG

- DETERMINE MACROSCOPIC CROSS-SECTION UAV<sub>LEFT</sub>

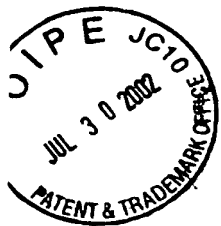
$$UAV_{LEFT} = \left[ \frac{K}{\left( \frac{\text{SOFT COUNT RATE } Q_{LEFT}}{\text{HARD COUNT RATE } Q_{LEFT}} \right)^{-B}} \right]^{-C}$$

- DETERMINE PEFAV<sub>LEFT</sub>

$$PEFAV_{LEFT} = \frac{UAV_{LEFT}}{PAVG_{LEFT}}$$

PEFAV<sub>LEFT</sub>

FROM  
FIG. 9  
PAVG<sub>LEFT</sub>

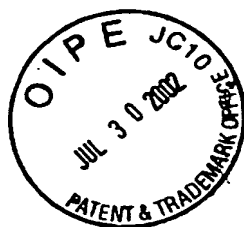


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330

FIG. 12A

335



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COMPUTER PROGRAM FOR ROTATIONAL PHOTOELECTRIC  
EFFECT (PEF) OUTPUTS

FROM  
FIG. 8

TOTAL SOFT WINDOW COUNT RATE  
SAMPLES LONG OR SHORT  
TOTAL HARD WINDOW COUNT RATE  
SAMPLES LONG OR SHORT  
COUNT RATES

FROM  
FIG. 10A-1  
 $P_{bROT}$

DETERMINE :

- THEORETICAL STANDARD DEVIATIONS (SOFT AND HARD)
- STANDARD DEVIATIONS OF SAMPLES (SOFT AND HARD)
- DELTA COUNT RATES (SOFT AND HARD)
- MACROSCOPIC CROSS-SECTION  $U_{ROT}$

$$U_{ROT} = \left[ \frac{K}{\left( \frac{\text{SOFT COUNT RATE} - \Delta CR_{SOFT}}{\text{HARD COUNT RATE} - \Delta CR_{HARD}} \right)^{-B}} \right]^{-C}$$

- $PEF_{ROT} = \frac{U_{ROT}}{P_{bROT}}$

$PEF_{ROT}$

FROM  
FIG. 8

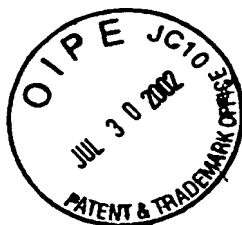
SOFT WINDOW COUNT RATE SAMPLES  
IN  $Q_{BOT}$  LONG OR SHORT  
HARD WINDOW COUNT RATE SAMPLES  
IN  $Q_{BOT}$  LONG OR SHORT  
COUNT RATES

TO FIG. 12B



FIG.12B

FROM FIG.12A



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FROM  
FIG.10A-1

PbROT<sub>BOT</sub>

335

DETERMINE:

- THEORETICAL STANDARD DEVIATIONS (SOFT AND HARD)
- STANDARD DEVIATIONS OF SAMPLES (SOFT AND HARD)
- DELTA COUNT RATES (SOFT AND HARD)
- MACROSCOPIC CROSS-SECTION UROT<sub>BOT</sub>

$$UROT_{BOT} = \left[ \frac{K}{\left( \frac{SOFT \text{ COUNT RATE} - \Delta CR_{SOFT}}{HARD \text{ COUNT RATE} - \Delta CR_{HARD}} \right)^B} \right]^{-C}$$

$$PEFROT_{BOT} = \frac{UROT_{BOT}}{PbROT_{BOT}}$$

PEFROT<sub>BOT</sub>

FROM  
FIG.8

SOFT WINDOW COUNT RATE SAMPLES  
IN Q<sub>RIGHT</sub> LONG OR SHORT  
HARD WINDOW COUNT RATE SAMPLES  
IN Q<sub>RIGHT</sub> LONG OR SHORT  
COUNT RATES

FROM  
FIG.10A-2

PbROT<sub>RIGHT</sub>

DETERMINE:

- THEORETICAL STANDARD DEVIATIONS (SOFT AND HARD)
- STANDARD DEVIATIONS OF SAMPLES (SOFT AND HARD)
- DELTA COUNT RATES (SOFT AND HARD)
- MACROSCOPIC CROSS-SECTION UROT<sub>RIGHT</sub>

$$UROT_{RIGHT} = \left[ \frac{K}{\left( \frac{SOFT \text{ COUNT RATE} - \Delta CR_{SOFT}}{HARD \text{ COUNT RATE} - \Delta CR_{HARD}} \right)^B} \right]^{-C}$$

$$PEFROT_{RIGHT} = \frac{UROT_{RIGHT}}{PbROT_{RIGHT}}$$

PEFROT<sub>RIGHT</sub>

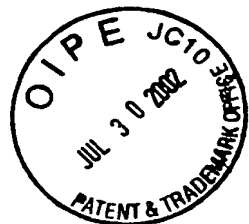
FROM  
FIG.8

SOFT WINDOW COUNT RATE SAMPLES  
IN Q<sub>TOP</sub> LONG OR SHORT  
HARD WINDOW COUNT RATE SAMPLES  
IN Q<sub>TOP</sub> LONG OR SHORT  
COUNT RATES

TO FIG.12C

FIG. 12C

FROM FIG. 12B

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FIG. 10A-2 $P_{bROT TOP}$ 

DETERMINE:

- THEORETICAL STANDARD DEVIATIONS (SOFT AND HARD)
- STANDARD DEVIATIONS OF SAMPLES (SOFT AND HARD)
- DELTA COUNT RATES (SOFT AND HARD)
- MACROSCOPIC CROSS-SECTION  $U_{ROT TOP}$

$$U_{ROT TOP} = \left[ \frac{K}{\left( \frac{\text{SOFT COUNT RATE} - \Delta CR_{SOFT}}{\text{HARD COUNT RATE} - \Delta CR_{HARD}} \right)^{-B}} \right]^{-C}$$

- $PEF_{ROT TOP} = \frac{U_{ROT TOP}}{P_{bROT TOP}}$

 $PEF_{ROT TOP}$ FROM  
FIG. 8

SOFT WINDOW COUNT RATE SAMPLES  
IN  $Q_{LEFT LONG}$  OR SHORT  
HARD WINDOW COUNT RATE SAMPLES  
IN  $Q_{LEFT LONG}$  OR SHORT  
COUNT RATES

FROM  
FIG. 10A-2 $P_{bROT LEFT}$ 

DETERMINE:

- THEORETICAL STANDARD DEVIATIONS (SOFT AND HARD)
- STANDARD DEVIATIONS OF SAMPLES (SOFT AND HARD)
- DELTA COUNT RATES (SOFT OR HARD)
- MACROSCOPIC CROSS-SECTION  $U_{ROT LEFT}$

$$U_{ROT LEFT} = \left[ \frac{K}{\left( \frac{\text{SOFT COUNT RATE} - \Delta CR_{SOFT}}{\text{HARD COUNT RATE} - \Delta CR_{HARD}} \right)^{-B}} \right]^{-C}$$

- $PEF_{ROT LEFT} = \frac{U_{ROT LEFT}}{P_{bROT LEFT}}$

 $PEF_{ROT LEFT}$

FIG. 12D

335



FROM  
FIG. 8

COMPUTER PROGRAM FOR ROTATIONAL PHOTOELECTRIC  
EFFECT (PEF) OUTPUTS

TOTAL SOFT WINDOW COUNT RATE SAMPLES LNG. OR SHT.  
TOTAL HARD WINDOW COUNT RATE SAMPLES LNG. OR SHT.  
ACQUISITION TIME SAMPLES

- DETERMINE MACROSCOPIC CROSS-SECTION  $U_t$ 's AS A FUNCTION OF ACQUISITION TIME

$$U_t = \left[ \frac{K}{\left( \frac{\text{SOFT COUNT RATE}}{\text{HARD COUNT RATE}} \right)^{-B}} \right]^{-C}$$

- DETERMINE STANDARD DEVIATION FROM  $U_t$ 's
- DETERMINE  $PEF_{ROT}$  FROM DISTRIBUTION OF  $U_t$ 's

→  $PEF_{ROT}$

FROM  
FIG. 8

SOFT WINDOW COUNT RATE SAMPLES IN  $Q_{BOT}$  LNG. OR SHT.  
HARD WINDOW COUNT RATE SAMPLES IN  $Q_{BOT}$  LNG. OR SHT.  
ACQUISITION TIME SAMPLES

- DETERMINE MACROSCOPIC CROSS-SECTION  $U_{tBOT}$ 's AS A FUNCTION OF ACQUISITION TIME

$$U_{tBOT} = \left[ \frac{K}{\left( \frac{\text{SOFT COUNT RATE}}{\text{HARD COUNT RATE}} \right)^{-B}} \right]^{-C}$$

- DETERMINE STANDARD DEVIATION FROM  $U_{tBOT}$ 's
- DETERMINE  $PEF_{ROTBOT}$  FROM DISTRIBUTION OF  $U_{tBOT}$ 's

→  $PEF_{ROTBOT}$

TO FIG. 12E

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**FIG.12E**

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FROM FIG.12D

FROM  
FIG. 8

SOFT WINDOW COUNT RATE SAMPLES IN QRIGHT LNG. OR SHT.  
HARD WINDOW COUNT RATE SAMPLES IN QRIGHT LNG. OR SHT.  
ACQUISITION TIME SAMPLES

335

- DETERMINE MACROSCOPIC CROSS-SECTION  $U_{RIGHT}$ 's AS A FUNCTION OF ACQUISITION TIME

$$U_{RIGHT} = \left[ \frac{K}{\left( \frac{\text{SOFT COUNT RATE}}{\text{HARD COUNT RATE}} \right)^{-B}} \right]^{-C}$$

- DETERMINE STANDARD DEVIATION FROM  $U_{RIGHT}$ 's
- DETERMINE  $PEFROT_{RIGHT}$  FROM DISTRIBUTION OF  $U_{RIGHT}$ 's

$PEFROT_{RIGHT}$

FROM  
FIG. 8

SOFT WINDOW COUNT RATE SAMPLES IN QTOP LNG. OR SHT.  
HARD WINDOW COUNT RATE SAMPLES IN QTOP LNG. OR SHT.  
ACQUISITION TIME SAMPLES

- DETERMINE MACROSCOPIC CROSS-SECTION  $U_{TOP}$ 's AS A FUNCTION OF ACQUISITION TIME

$$U_{TOP} = \left[ \frac{K}{\left( \frac{\text{SOFT COUNT RATE}}{\text{HARD COUNT RATE}} \right)^{-B}} \right]^{-C}$$

- DETERMINE STANDARD DEVIATION FROM  $U_{TOP}$ 's
- DETERMINE  $PEFROT_{TOP}$  FROM DISTRIBUTION OF  $U_{TOP}$ 's

$PEFROT_{TOP}$

TO FIG.12F

FIG.12F

FROM FIG.12E

FROM  
FIG. 8

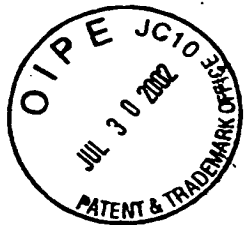
SOFT WINDOW COUNT RATE SAMPLES IN QLEFT LNG. OR SHT.  
HARD WINDOW COUNT RATE SAMPLES IN QLEFT LNG. OR SHT.  
ACQUISITION TIME SAMPLES

- DETERMINE MACROSCOPIC CROSS-SECTION  $U_{LEFT}$ 's AS A FUNCTION OF ACQUISITION TIME

$$U_{LEFT} = \left[ \frac{K}{\left( \frac{\text{SOFT COUNT RATE}}{\text{HARD COUNT RATE}} \right)^{-B}} \right]^{-C}$$

- DETERMINE STANDARD DEVIATION FROM  $U_{LEFT}$ 's
- DETERMINE  $PEFROT_{LEFT}$  FROM DISTRIBUTION OF  $U_{LEFT}$ 's

→  
 $PEFROT_{LEFT}$



335

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FIG.13

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### COMPUTER PROGRAM FOR ULTRASONIC STANDOFF OUTPUTS

FROM  
FIG. 4A-B

- RECORD STANDOFF AS A FUNCTION OF QUADRANT
- DEVELOP HISTOGRAM OF ALL STANDOFFS AND HISTOGRAM OF STANDOFFS PER QUADRANT
- DETERMINE  $STANDOFF_{AVG}$ ,  $STANDOFF_{MAX}$ ,  $STANDOFF_{MIN}$  FOR EACH QUADRANT
- DETERMINE HOLE SHAPE:  
HORIZONTAL DIAMETER  
VERTICAL DIAMETER

→  
H DIAMETER

→  
V DIAMETER

FIG.14A

340

COMPUTER PROGRAM FOR AVERAGE  
NEUTRON POROSITY

FROM  
FIG.4A-B  
FROM  
FIG.13

FAR NEUTRON COUNT RATE  
NEAR NEUTRON COUNT RATE  
H DIAMETER OF HOLE  
V DIAMETER OF HOLE

• DETERMINE AVG NEUTRON  
POROSITY

POROSITY<sub>AVG</sub>

FROM  
FIG.4A-B  
FROM  
FIG.13

FAR NEUTRON COUNT RATE IN Q<sub>BOT</sub>  
NEAR NEUTRON COUNT RATE IN Q<sub>BOT</sub>  
H DIAMETER OF HOLE  
V DIAMETER OF HOLE

• DETERMINE AVG NEUTRON  
POROSITY<sub>BOT</sub>

POROSITY<sub>AVG BOT</sub>

FROM  
FIG.4A-B  
FROM  
FIG.13

FAR NEUTRON COUNT RATE IN Q<sub>RIGHT</sub>  
NEAR NEUTRON COUNT RATE IN Q<sub>RIGHT</sub>  
H DIAMETER OF HOLE  
V DIAMETER OF HOLE

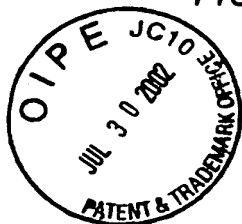
• DETERMINE AVG NEUTRON  
POROSITY<sub>RIGHT</sub>

POROSITY<sub>AVG RIGHT</sub>

FROM  
FIG.4A-B  
FROM  
FIG.13

FAR NEUTRON COUNT RATE IN Q<sub>TOP</sub>  
NEAR NEUTRON COUNT RATE IN Q<sub>TOP</sub>  
H DIAMETER OF HOLE  
V DIAMETER OF HOLE

TO FIG.14B



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FIG. 14B

FROM FIG. 14A

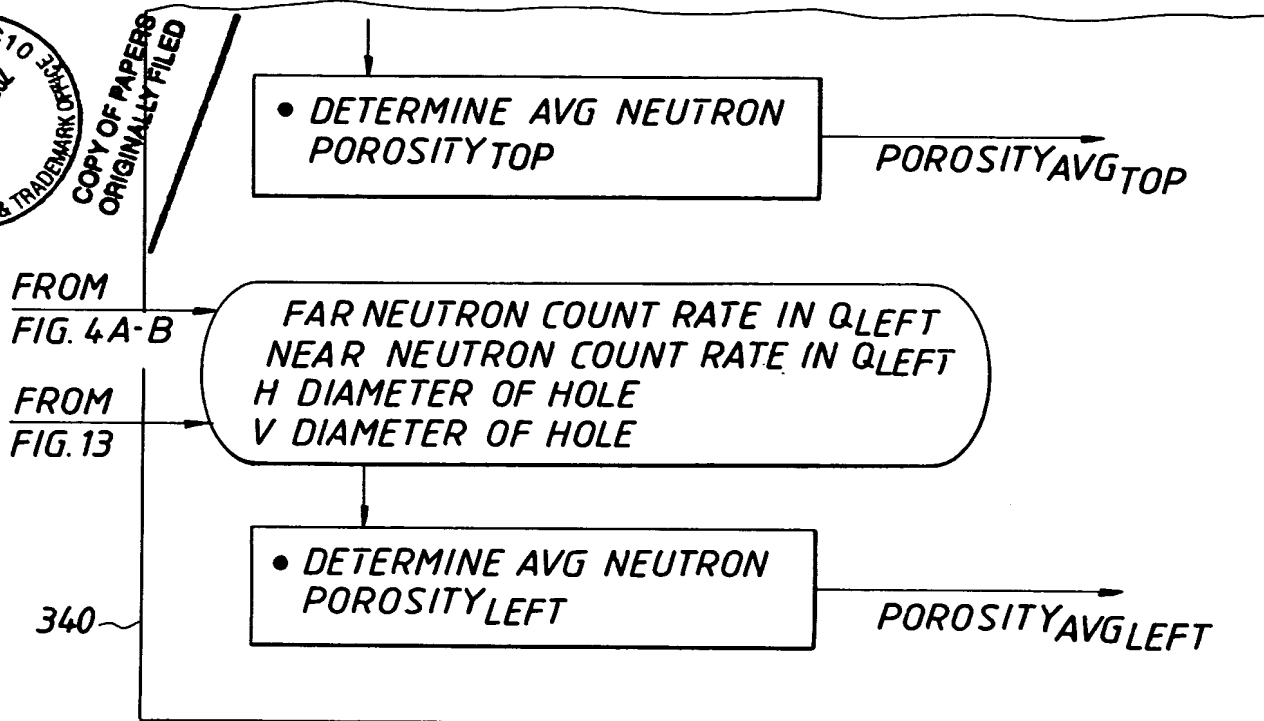
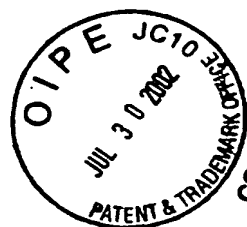


FIG. 15A

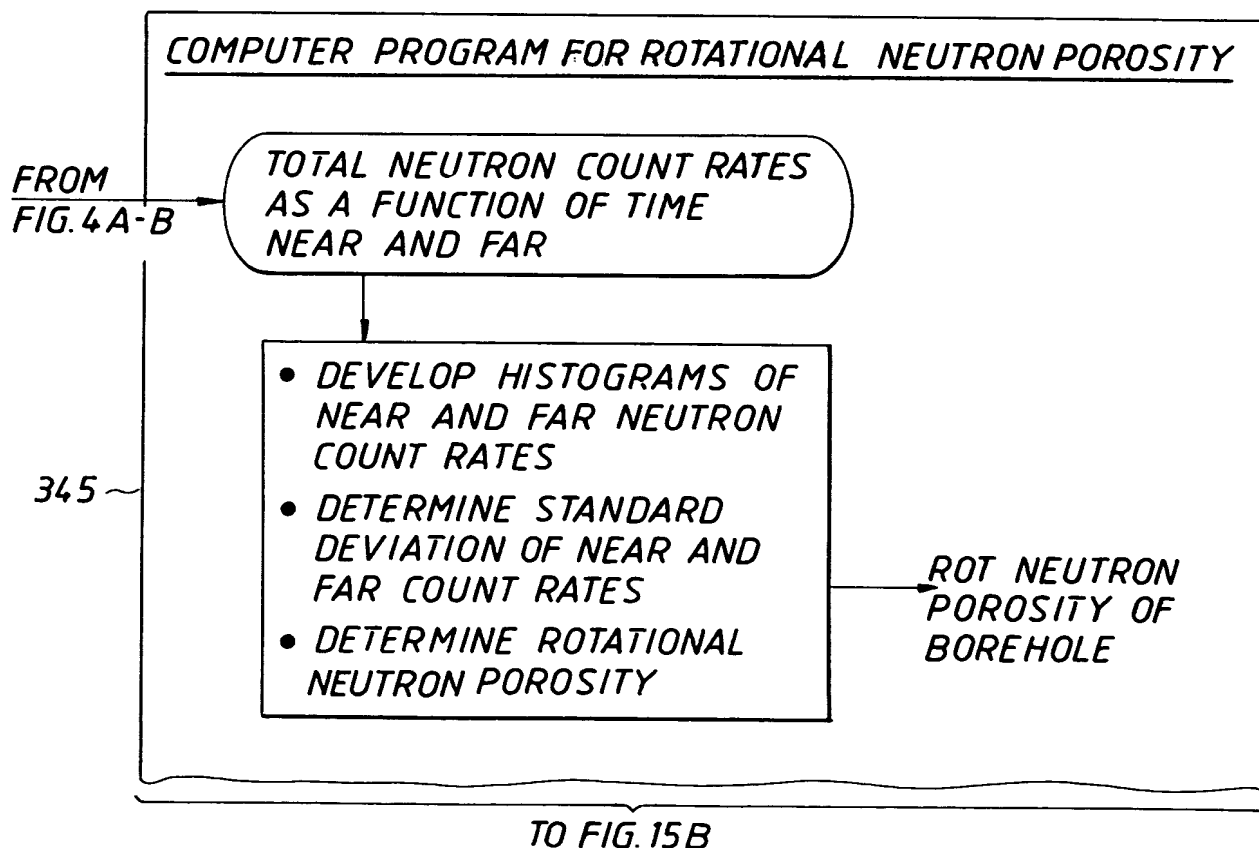
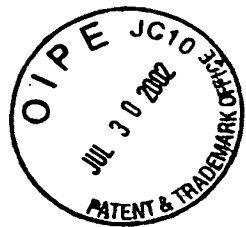


FIG.15B



FROM  
FIG.4A-B

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NEUTRON COUNT RATES IN QBOT  
AS A FUNCTION OF TIME NEAR  
AND FAR

- DEVELOP HISTOGRAMS OF NEAR AND FAR NEUTRON COUNT RATES
- DETERMINE STANDARD DEVIATION OF NEAR AND FAR COUNT RATES
- DETERMINE ROTATIONAL NEUTRON POROSITY IN QBOT

ROT NEUTRON  
POROSITY  
IN QBOT

FROM  
FIG.4A-B

NEUTRON COUNT RATES IN QRIGHT  
AS A FUNCTION OF TIME NEAR  
AND FAR

- DEVELOP HISTOGRAMS OF NEAR AND FAR NEUTRON COUNT RATES
- DETERMINE STANDARD DEVIATION OF NEAR AND FAR COUNT RATES
- DETERMINE ROTATIONAL NEUTRON POROSITY IN QRIGHT

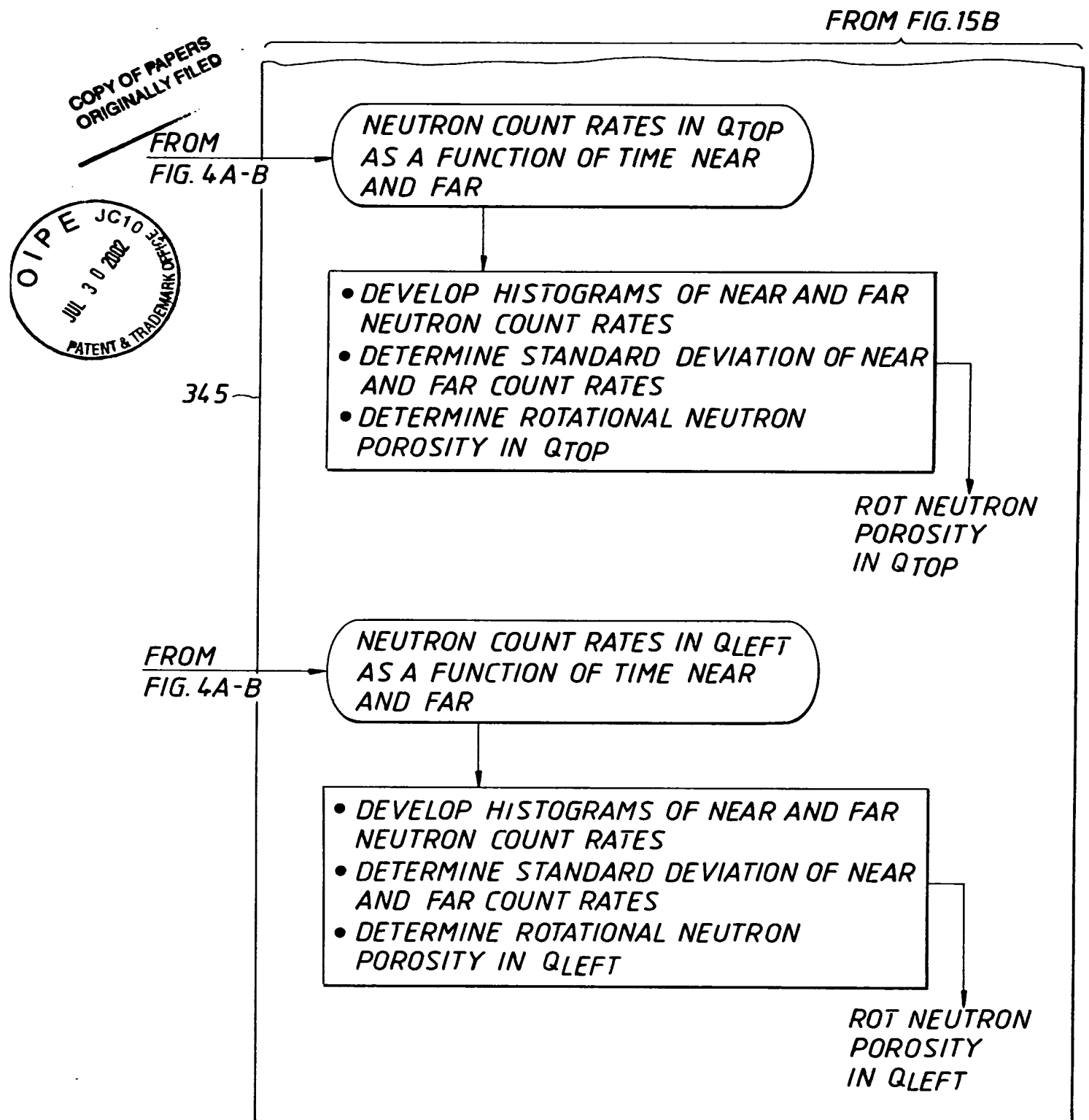
ROT NEUTRON  
POROSITY  
IN QRIGHT

TO FIG.15C

FROM FIG.15A



FIG. 15C



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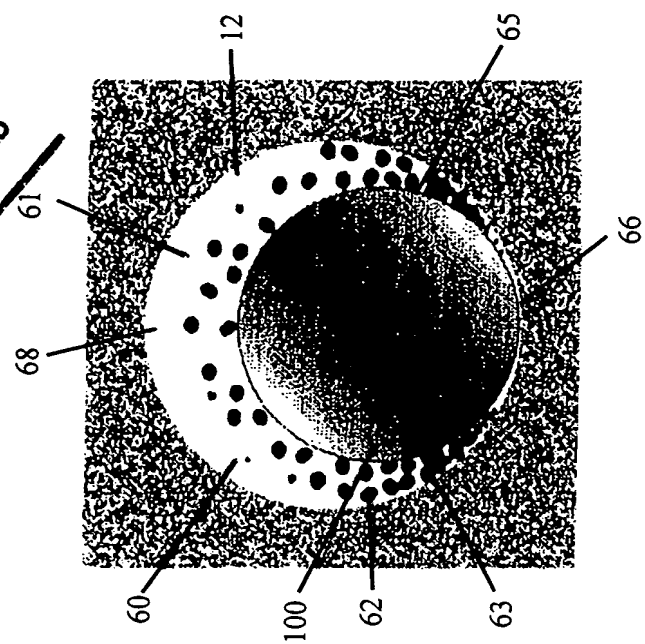


FIG. 16B

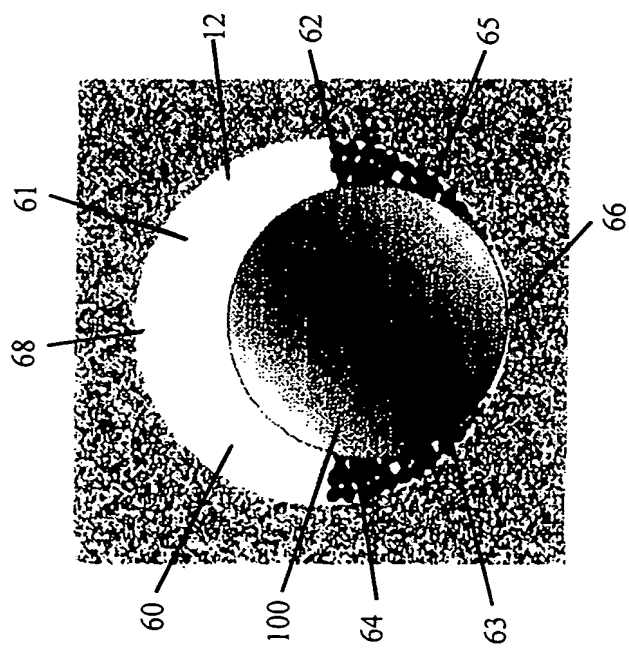
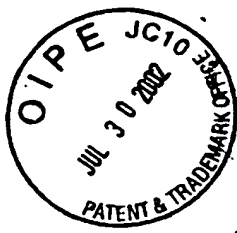


FIG. 16A



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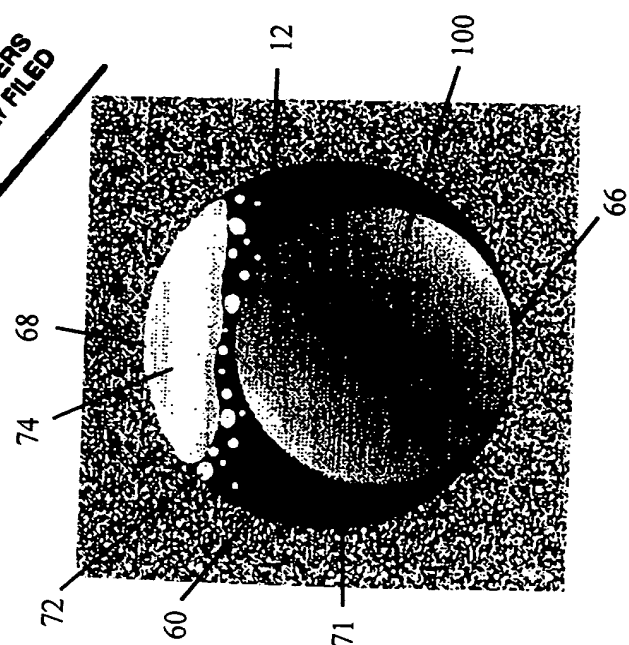


FIG. 17B

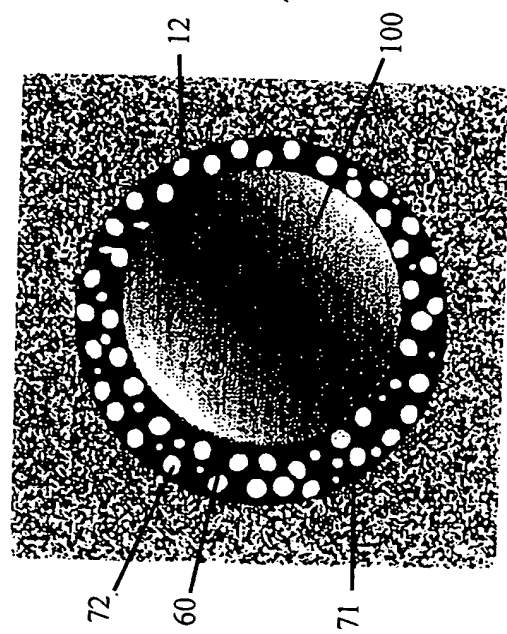


FIG. 17A